PUPILS' OUTLINES FOR HOME STUDY

IN CONNECTION WITH SCHOOL WORK

PHYSICS, PART II

Sound, Heat, Light, Magnetism, Electricity

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SOUND.

Sound is a vibration moving in a wave motion capable of producing the sensation of hearing.

Production. Sound is produced by the rapid vibrations of a body.

EXPERIMENTS:

(*a*) A tight cord set in vibration produces a sound.

(*b*) Strike a tuning-fork and bring it in contact with some water and a wave will be produced.

Media or Medium of Sound is the material through which sound travels. It must be elastic. Gases, liquids and solids all transmit sound, but with different degrees of intensity and velocity.

EXPERIMENTS:

(*a*) Ring a bell and we hear a sound, showing it was transmitted through a gas, the air.

(*b*) Swimming under water one can hear a noise made under the water more readily than if the same occurred above the surface, showing that a liquid transmits sound.

(*c*) Place the ear at one end of a long stick, gently scratch a pin on the other end, the sound not audible under ordinary circumstances is distinctly heard, showing that sound may be transmitted through a solid.

(*d*) Placing one's ear against a telegraph pole we hear the sounds of the wires distinctly.

Sound will not be transmitted in a vacuum.

EXPERIMENT—Place a bell under the receiver of an air pump, and pass both the wires of the bell through a stopper in the receiver and connect it with a battery, then ring the bell and a distinct sound is heard. Exhaust the air and again ring the bell, the more the air is exhausted the fainter becomes the sound.

VELOCITY.

Velocity of sound depends upon the elasticity and the density of the medium. The speed in air increases with an increase of temperature.

At 32 degrees Fahrenheit the velocity in air is little over 1,090 feet per second, at 60 degrees Fahrenheit it is about 1,120 feet per second. Its velocity in water is about 4 3-10 times as great as in air; about 11 times as great in copper; and in iron 15 times as great.

EXPERIMENT—That sound takes time to travel is shown in the difference in time between the flash and the report of a gun.

REFLECTION.

Echo is reflected sound. This reflection takes place whenever the motion of a sound wave reaches a medium of different density. The time that elapses between the production of the sound and the hearing of the echo is the time it takes the sound to reach the reflecting surface, and return to the source.

The LENGTH of the sound repeated depends on the distance of the reflecting bodies.

A Multiple Echo is one which is repeated many times because of successive reflections; as, a sound between parallel cliffs.

If the reflected sound returns before the original sound has died out, no echo is heard and the sound is strengthened; hence, we get no echo in an ordinary-sized room. In larger rooms where an echo is apt to occur, draperies are usually hung to break the sound waves. Walls closer than fifty feet cannot produce an echo.

Sounds may be reflected from solids and liquids.

INTENSITY OF SOUND.

This means its loudness. It depends on the amplitude of vibration, that is the distance through which the individual particles swing.

Intensity Depends on

1. **Amplitude** of vibration or the energy with which the body is sounded.

   EXPERIMENT—Strike a stretched string lightly, and then with more force. The sound produced the second time was louder than the first time.

2. **Distance from Sounding Body.**

   EXPERIMENT—Distance causes the waves of sound to grow larger and larger and hence weaker; as a stone thrown in water produces rings about it which increase in size the further they are found from the stone.

3. **Density of Medium.**

   EXPERIMENT—The more dense the medium, the sooner one particle sets the next in motion and the less force is lost. Strike a tuning-fork in air, then rest the handle on a piece of iron and the sound becomes more distinct.

In the ear trumpet, megaphone and speaking tube the sound waves are reflected from the inside and cannot spread to a larger area, and so the sound waves are carried long distances with little loss of intensity.

PITCH.

The **Pitch** of sound is its degree of highness or lowness.

The Pitch *depends* on the number of vibrations per second, the more vibrations per second the higher the pitch.

EXPERIMENT—Draw a stick along a picket fence slowly, then rapidly, and note the difference in the sound.

ILLUSTRATIONS—Cricket, buzzer.

EXPERIMENT—Water poured into a tall glass cylinder produces different sounds as the length of the air column changes, the column growing smaller more vibrations are produced and the sound becomes shriller, the force remaining the same

TIMBRE.

Timbre is the equality of sound. It depends on the manner of vibration as bodies not only vibrate as a whole but in various parts. Thus notes of the same pitch sounded on a piano and a violin can easily be distinguished owing to the *quality* or *timbre* of the sound.

MUSIC AND NOISE.

If the sound waves come at regular intervals and so rapidly that the ear does not distinguish intervals, we have a continuous sound which is pleasant and is known as a *musical* tone or sound; but if the intervals are distinguished and do not come with regularity we have an unpleasant sound produced, known as *noise*.

MUSICAL SCALE.

This is a standard series of seven tones selected for musical purposes; vibrating in the ratio of

C	D	E	F	G	A	B	C	
1	9-8	5-4	4-3	3-2	5-3	15-8	2	(Ratio of Vibration)

That is D has 9-8 as many vibrations as C; E has 5-4 as many as C, etc.

C	D	E	F	G	A	B	C	(Scale Names)
256	288	320	341	384	427	480	512	(Number of Vibrations)

In music, the notes or tones are represented by different positions on the staff (five lines and four spaces).

The "one" is known as the keynote of the scale and gives the name by which the scale is designated; as the above, is the scale of "C."

In this scale there are half tones between three and four and seven and eight while between all the others there are whole tones. This is true of all major scales. In order to change from one to another of the major scales we make "five" of the preceding scale "one" or the keynote of the new and by using flats or sharps keep the whole tones throughout, except at three and four and seven and eight where we must have semi-tones.

INTERVALS.

1. **Octave.** The interval between two notes one having twice as many vibrations as the other is known as the octave; as "C" having 256 vibrations, if we strike a note having 512 we produce C an octave higher which is the eighth note in the scale or the first of the next octave.
2. There are also intervals of *seconds* as C to D, D to E, E to F; or of *thirds,* as C to E; and *fifths,* as C to G, etc.

In making a musical instrument any number of vibrations may be taken for C provided the above ratio is kept after that in arranging the other notes. 256 vibrations is usually taken as middle C in laboratory work; but the majority of pianos have 258.

HARMONY AND DISCORD.

Two tones sounded together are in HARMONY if they produce a pleasant effect on the listener. This occurs when the ratio of vibration between the notes is simple, as 4:5, or 1:2, or C to C.

Two tones sounded together producing an unpleasant and disagreeable sound are said to produce a DISCORD. This occurs when the ratio of vibration between the notes is not simple as 2 to 15-8 or C to B.

MUSICAL INSTRUMENTS.

Classes.

1. **Stringed Instruments** are those from which sound is produced by the vibrations of a stretched wire or catgut.

These strings may produce differences in *pitch, intensity* and *timbre.*

PITCH of the *vibrating strings* depends on the differences in *length, thickness* and *tension* of the strings.

(*a*) The SHORTER the string the more rapid the vibrations, hence the HIGHER the note.

Experiment—Sound one string on a sonometer, then divide another string in half and sound it and the octave higher will be produced on the second string.

(*b*) The lighter or thinner the string the more vibrations are produced and hence a higher note.

Experiment—Bass and treble strings of a piano.

(*c*) The more tightly a string is stretched the greater the number of vibrations, and, hence, the higher the note.

Experiment—Sound a string on a sonometer, tighten it and sound it again, comparing the tones.

2. **Wind Instruments** are those from which sound is produced by the vibration of columns of air of different lengths.

Experiment—Sound a tuning-fork and hold it over a glass cylinder as water is being poured into the cylinder, and note the difference in tone as the length of the column of air decreases.

The *pitch* of a closed pipe is an octave lower than that of an open pipe of equal length.

Wind Instruments Are of Two Classes.

a. **Mouth Instruments.** Those in which the column of air is set vibrating by blowing across the mouth or the narrow opening at the end of the pipe; as in the organ, flute, fife, piccolo, and in whistles. The air chamber may be either closed or opened at the further end.

Pipe organs have different pipes for each note, but the other instruments mentioned produce different notes by opening and closing holes in the side of the tube which really means to lengthen or shorten the length of air in the column.

b. **Reed Instruments.** Those in which the column of air is set vibrating by a thin wooden or metal plate which is itself set in rapid vibration by a strong current of air; as clarinet and reed organ, bassoon, accordion.

The cornet and bugle are practically reed instruments, but the lips of the musician take the place of the vibrating plate.

VOICE.

Speech is the human voice effected by the lips, tongue, teeth and other parts of the mouth.

Across the top of the larynx are stretched two whitish membranes known as the vocal cords. When no sound is being produced the vocal cords are loose and widely separated, permitting a large column of air to be sent out from the lungs. When a sound is to be produced, through muscular action the cords become tense, and close together; the air from the lungs then sets them in vibration and sounds are produced which may vary in *intensity* and *pitch*.

The pitch here as in musical stringed instruments depends on the length, thickness and tension of the cords. The shorter, thinner and more tense the vocal cords, the more vibrations are produced and hence the higher the pitch.

Illustration—A woman's voice is ordinarily higher pitched than a man's voice.

THE EAR.

The ear consists of three different parts.

1. **Outer Ear.** This consists of the curved piece of gristle on the side of the head, the auditory canal leading to the ear drum, and the elastic membrane.

2. **Middle Ear.** This is the cavity just beyond the ear drum. Across it are found three tiny bones which from their shape are known as the hammer, anvil and stirrup. The first being attached to the inner side of the ear drum, and the third forming a division between the middle and inner ear. A small opening called the eustachian tube connects the middle ear and throat.
3. **Inner Ear.** This contains three parts, the space known as the vestibule, the semi-circular canals, and the cochlea which connects with the auditory nerve. The whole is filled with a fluid.

Hearing. The vibrations of an object are transmitted through the air to the ear where they are collected in the curved part and then pass through the auditory canal setting the ear drum in vibration, this in turn is transmitted through the bones of the middle ear, and thus is brought to the bones and fluid of the inner ear, and so reaches the auditory nerve from whence it is carried to the brain and we realize we have heard the sound.

HEAT.

Heat is the force which produces the sensation of warmth or cold. It is due to the motion of the molecules of matter; if this rapidity of motion of the molecules is increased the heat of the body increases and visa versa.

Sources of Heat.

1. SUN. Experiment.—Place a piece of glass in the sun and notice the change in its temperature in a short time.
2. MECHANICAL MEANS.

   (*a*) PERCUSSION. Experiment—Strike several blows with a hammer on a nail head and the nail becomes appreciably warmer.

   (*b*) FRICTION. Experiment—Rubbing the hands together briskly makes them warmer.

   (*c*) COMPRESSION. Experiment—In filling the rubber tire of a bicycle with a hand pump the sides of the pump become warm after the piston has been driven up and down a few times.
3. CHEMICAL ACTION.

   (*a*) COMBUSTION. Experiment—Burning of a match.

   (*b*) CHEMICAL COMBINATION. Experiment—Pour water on lime and it begins to boil.

   (*c*) ELECTRICITY. Heat given out near an electric light.
4. INTERIOR OF EARTH. The deeper we descend into a mine the warmer it becomes.

TEMPERATURE.

This is the state of matter in regard to heat. It is the condition of a body with reference to its ability to give heat to other bodies or to take heat from them. Temperature is not heat itself nor the quantity of heat.

Experiment—Remove a glass full of water from a pail full of hot water, the water in both vessels has the same temperature, but there is more heat in the pail full than in the glass.

MEASUREMENT OF TEMPERATURE.

A body seems warm if it imparts heat to us, and cold if it takes heat from us; therefore we cannot depend upon ourselves in measuring or determining temperature, but should use an instrument known as a *thermometer* for measuring temperature.

THERMOMETER.

This is an instrument for measuring temperature. It is a glass tube with a capillary bore ending at one end in a bulb. It is partly filled with mercury or alcohol and fastened to a graduated scale. Above the mercury is a partial vacuum.

The two thermometers mostly used are the Fahrenheit and the Centigrade. There are two fixed points on each, the "boiling point" and the "freezing point." These are determined by plunging the tube of mercury into a perforated pail of ice so that the water will drain off and allowing it to remain till the mercury becomes settled, this point is then marked as "freezing" point. The same tube of mercury is suspended in a vessel of steam and allowed to remain till the mercury comes to rest and this point indicated as the "boiling" point.

In the Fahrenheit thermometer the boiling point is 212 degrees and the freezing point 32 degrees. The space between these two points is evenly divided into 180 parts called degrees.

In the Centigrade the boiling point is 100 degrees and the freezing point is zero, and the space between evenly divided into 100 parts or degrees.

CHANGING FROM ONE SCALE TO THE OTHER.

100° Centigrade are equal to 180° Fahrenheit, so 1° Centigrade is equal to 9/5° Fahrenheit.

The number of degrees given on a Fahrenheit scale is not the actual number of degrees from the freezing point as it is on the Centigrade; for instance, 5° below zero in the Fahrenheit scale would really be 37° or 32° plus 5° below freezing.

Hence in changing from (a) Fahrenheit to Centigrade subtract 32 from the given number of degrees and multiply by 5/9; (b) Centigrade to Fahrenheit multiply the given number of degrees by 9/5 and then add 32.

EFFECTS OF HEAT.

1. **On Solids.**

(*a*) FUSION changes the form sometimes from a solid to a liquid; as, in ice, iron.

(*b*) EXPANSION.

Experiment—Difference in the amount of heat in summer as compared with that of winter causes the telephone and telegraph wires to expand so that they sag perceptibly. Steel suspension bridges are lower in the middle in summer than in winter owing to expansion. Steel structures are riveted with red hot bolts because the parts are better held together when the bolts cool and contract. Tires are red hot when put on wheels and cooling, contract and fit more tightly. In laying rails spaces are left for expansion and contraction of the iron.

2. **On Liquids.**

(*a*) CHANGING of FORM from a liquid to a gas. Heat water, and vapor rises until no water remains.

(*b*) EXPANSION. Water boiling in a kettle lifts the lid, to obtain more room, as liquids expand upon being heated.

A liquid is lighter when warm than when cold. By this principle houses are heated with hot water. The hot water rises and passes through radiators and returns to the heating plant.

3. On Gases.

(*a*) EXPANSION. A boiler filled with steam becomes heated, and if the steam cannot escape the boiler bursts.

WINDS.

Heated air becomes lighter and rises, and cool air comes in to replace it. This causes a vertical current of air over a heated surface and a horizontal current from places just beyond the heated body, hence on each side of the equator we have "trade winds" blowing towards the heated surface, and at the equator an ascending current which passes off into the upper air.

VAPORIZATION.

The changing of a liquid into a gaseous form, vapor, is called *vaporization.*

(*a*) **Evaporation** is the quiet and rather slow formation of vapor at the surface of an exposed liquid. The greater the extent of surface exposed the greater is the rapidity of evaporation.

Experiment—Pour an equal amount of water into a large shallow pan and into a small tumbler. Expose this to the sun. In a short time the water in the pan will entirely have disappeared, while a considerable amount still remains in the glass.

(*b*) **Ebullition or Boiling** is the rapid formation of bubbles of vapor throughout a liquid, but in greatest number and rapidity at the point where the heat is applied.

Experiment—Place a pan of water over the fire, when it begins to boil note the rapid formation of bubbles rising from the bottom of the liquid to the surface.

CONDENSATION OF LIQUEFACTION.

The changing of vapor to a liquid state is known as condensation or liquefaction.

Experiment—Hold a glass over the spout of a kettle of boiling water and soon drops of water will be deposited on the glass.

Illustration—Formation of dew, fog, rain, hail, clouds.

These depend on the state of the air with regard to the amount of water vapor it contains. The higher we increase the temperature of a certain space of air the more vapor it can hold. When a point is reached where the given space at a given temperature can hold no more vapor, we have reached the point of *saturation* or *dew point.* If for any reason the temperature is lowered it cannot hold the same amount of vapor, and some of it is condensed to a liquid and forms, according to its location and the condition of bodies within it, either dew, fog, rain, clouds, etc.

Dew. During the day the earth gains more heat by radiation than it loses, but as soon as the sun sets this is reversed. Then everything begins to cool and the air surrounding these objects condenses and collects in tiny drops of liquid on their surfaces. Dew collects freely on grass and leaves because they cool quickly, while the earth and stones do not radiate so well and consequently we do not find as much dew on them.

Fog, Clouds. If a mass of moist warm air comes in contact with a mass of cold air near the earth's surface we have a fog; if it occurs at some distance above the earth, we say a cloud is formed.

Rain. If the moisture in the cloud condenses we have rain.

Dry Air. If the existing temperature is much higher than dew-point it is capable of holding a considerably greater quantity of vapor so the air is said to be *dry.*

Humidity or Humid Air. If the temperature is only a little above the dew-point it can only retain but very little more vapor, the air being nearly saturated; so we say there is a *humid air,* or there is *humidity.*

TRANSFERENCE OF HEAT.

1. **Conduction** is the flow of heat through a body by passing from molecule to molecule. This is the case when heat passes from places of higher temperature to those of lower; or, the passing of heat through a body unequally heated. The body through which the heat is passing is known as a *conductor.* Metals are excellent conductors of heat while glass and wood are non-conductors. Liquids and gases are also poor conductors. Solids are mainly heated by conduction.

   Experiment—Thrust a long piece of iron into the fire and holding it with one hand. With the other hand thrust in a stick of wood and note that we can only hold the iron a very short time before it becomes hot enough to almost burn our fingers, while this is not the case with the wood.

   Experiment—In a room warmer than the body, test the actual heat of various objects by applying the thermometer to them and note that the temperature is about the same for all. Now place the hand against each in turn and we find apparently a considerable difference in temperature. Those which seem warmest are the best conductors, giving us their heat more quickly than the others which consequently do not seem as warm. The opposite is true in a room which is colder than our body.

   Clothes which are bad conductors may therefore exclude the heat in summer and the cold in winter.

2. **Convection.** The process of heating a body by the circulation of the molecules is known as *convection.* Liquids and gases are heated by convection.

   (*a*) Convection in Liquids. Experiment—Into a small thin flask pour boiling water which has been colored, and after corking the bottle lower into a deep vessel of cold water and remove the cork. We find that the liquid being hot and rarer rises from the bottle and the cold, heavier liquid sinks into the bottle to replace the colored liquid and the two currents are seen moving separately and distinctly.

   Illustration—Gulf stream and ocean currents show convection currents.

   (*b*) Convection in Gases. Experiment—Cut a small circle of holes towards one side of the cover of a pan and place a lighted candle in the center of them with a chimney over them. On the other side of the cover of the pan cut another hole and place a chimney over it. Hold a piece of smoking paper over the second chimney and the smoke descends, goes through the pan and comes out of the first chimney.

   Illustration—Ventilating mines. Two shafts take the place of the two chimneys while the mine corresponds to the covered pan. Sea and land breezes, winds, trade winds, are all examples of convection in currents of air.

LAND AND SEA BREEZES.

During the day the land is heated more rapidly than the sea because the specific heat of water is greater than that of the earth. The hot air rises over the land and cold air from the sea rushes in to take its place, giving us a seabreeze which blows during the day.

At night the earth cools more rapidly than the sea, so the direction of the wind is reversed and gives the land breeze which blows at night.

These winds are more noticeable in the tropics because there we find such a great difference between the temperature of day and night.

Trade Winds occur in the torrid zone. The air over the earth becomes heated and expanding rapidly becomes rarer than the surrounding air and rises. A colder air from the polar region pours in laterally on both sides to take the place of the ascending current giving us a constant wind from the northeast in the Northearn Hemisphere and one from the southeast in the Southern Hemisphere. The easterly direction is due to the rotating of the earth.

3. **Radiation.** This is a process by which a body throws off heat in every direction. Heat creates wavelike motions of the ether and the body obstructing these waves, transforms this energy of motion into heat. It is the radiation not the heat that travels.

ILLUSTRATION—The heating of the earth by the sun.

Tarnished, rough, dark surfaces radiate much better than bright smooth surfaces.

Absorption is the process by which a body takes heat into itself in a given time. Surfaces that make good radiators are also good absorbers.

Reflection is the ability a body has of sending out heat. Bright surfaces reflect well.

REAL AND SENSIBLE HEAT.

Heat a kettle of water to the boiling point and heat a nail red hot. The nail feels hotter than the water, so we say it has more *sensible heat* than the water. Allow them to cool and we find the water retains its heat longer than the nail, so we say it has more *real heat.*

LATENT HEAT AND SENSIBLE HEAT.

The heat which changes a body from a solid to a liquid or from a liquid to a gas without change of temperature is called *latent heat.* The heat which is expended in raising the temperature of a body is *sensible heat.*

ARTIFICIAL COLD.

A body becomes cold by losing heat; and heat passes only from warmer to colder surfaces so the temperature of any body cannot under ordinary circumstances fall below that of neighboring bodies; hence, if a lower temperature is desired it must be produced by artificial means.

In changing a solid to a liquid or a liquid to a gas a certain amount of heat is expended and this may be used to produce artificial cold.

(*a*) **Heat Used in Liquefaction—Freezing Mixtures.**

EXPERIMENT—Fill a test tube with water and place it in a bowl containing a freezing mixture of ice and salt (three of ice or snow to one of salt). The salt tends to melt the ice and the water to absorb the salt, both processes consuming heat; we find that soon the water in the test tube is frozen. If a second test tube of water was placed in plain ice we would find that in a given time the water had not frozen as in the first test tube.

(*b*) **Heat Used in Evaporation.** The heat consumed by evaporation is greater than that by liquefaction. Evaporation is increased by a rise in temperature, by a greater extent of exposed surface, by a lessening of pressure and by a dry atmosphere. When evaporation is rapidly increased it hastens the lowering of the temperature.

EXPERIMENT—Pour ether into the hand. It quickly evaporates and produces a cold sensation.

Bathing the head with alcohol will reduce the temperature and cool it.

ILLUSTRATION—In warm climates drinking water is kept in *porous* bottles which present a large surface for evaporation in order that the water may be kept at a low enough temperature for drinking.

ICE MACHINE.

This consists of a pump for compressing gas usually ammonia or carbon dioxide. This warms the gas and it is conducted to a coil of pipes which are cooled by streams of cold water. When the cooled gas is permitted to expand it readily absorbs heat and lowers the temperature. Sometimes the pipes are covered with a freezing mixture of some salt solution. The gas after it is used returns to the pump to be used again. The pump is worked by the steam engine.

USE—Refrigerators, cold-storage, manufacture of ice, and liquid air.

STEAM ENGINE.

This is a machine for using the expansive force of steam as a motor agent; as this property of steam is due entirely to heat we may call this a heat engine.

The important parts are the cylinder, piston, slide valves and boiler in which the steam is generated.

The piston is driven forward and backward in the cylinder. By an arrangement the slide valve moves to and fro in the steam chest and thus conducts the steam to each side of the piston alternately, and having done its work (driving the piston) is discharged alternately from each side of the piston either into the air or into a closed box in which the steam is condensed.

The motion of the piston is utilized to drive other machines or propel the engines.

HIGH AND LOW PRESSURE ENGINES.

The steam after it has done its work in moving the piston passes through the exhaust pipe to a box called a condenser. A spray of cold water is admitted at the same time condensing the steam into water, this is pumped out by an air pump thus a partial vacuum is formed and kept. This is known as a *condensing* engine or a *low pressure* engine. There is constantly an atmospheric pressure of 15 pounds to every square inch, so on the exhaust side of the piston by recreating a partial vacuum a great deal of this pressure is removed and an equal portion of pressure on the steam side is made use of to do the work. In a good engine of this kind instead of the piston working against 15 pounds pressure it works only against 1½ pounds per square inch.

An engine where the steam is blown out into the air instead of a condenser is known as a *non-condensing* engine or a *high pressure* engine, and here the steam moves the piston at a pressure from the atmosphere of 15 pounds to every square inch of surface of the piston.

Illustration—Steamboat engines are usually condensing engines. Locomotives and most engines in factories are high pressure engines.

LOCOMOTIVE.

The main feature of a locomotive is the great amount of space in comparison to its size and weight, that is given over to the generating of steam. In an hour an average of 5 tons of water must be changed to steam. This is done by bringing the water in contact with a large area of heated pipe running through the boiler, often as many as 150, and these are kept hot by the heated gas and smoke passing through them constantly between the fire box and the smoke stack and smoke box.

The steam is also generated by the rapid burning of coal in the fire box, sometimes as much as a ton is used in an hour.

The steam engine is a very wasteful machine, making use of only a small amount of the heat generated.

GAS ENGINE.

A mixture of air and coal gas or gasolene vapor is introduced into a cylinder. When full, the supply is cut off and the mixture in the cylinder exploded by an electric spark or flame. This raises the temperature of the enclosed gas and it expands and drives the piston forward. The products of combustion are then expelled by the return stroke of the piston. The third stroke draws a new supply of the mixed gas into the cylinder and the return stroke compresses them and they are then exploded. Some means must be provided for cooling the cylinder as the explosion of the gases produces great heat.

Uses—Automobiles, motor cycles, motor boats, movable wood sawing apparatus, etc.

LIGHT.

1. **Classes of Bodies.**
   (*a*) Luminous Bodies. Those which throw out light of their own, as the *Sun.*
   (*b*) Non-Luminous or Illuminated Bodies. Those which are seen by the light of another body, as the moon.
   (*c*) Medium. Anything through which light passes.
   (*d*) Transparent Bodies. Substances through which light passes and through which objects may be distinctly seen, as glass.
   (*e*) Translucent Bodies. Substances through which light passes, but through which bodies cannot be distinctly seen; as mica, paper.
   (*f*) Opaque Bodies. Substances through which light does not pass and through which an object cannot be seen, are opaque; as wood.
2. **Sources of Light.**
   (*a*) Sun.
   (*b*) Chemical Action; as, light from a match.

3. **Light** is a force coming from some luminous body which is capable of producing the sensation of sight.

4. **Propagation.** Light is produced by a rapid vibration in ether which is a substance between the earth and the sun.

5. **Motion.** Light is carried in waves to the eye and travels in straight lines.

   Experiment—Place a screen with a pinhole perforation between a lighted candle and the observer. When the perforation, candle and eye are in a direct line the flame is visible; move the screen slightly and the flame is invisible, showing that it does not curve around the edges of the screen to the eye. This is entirely different from sound, as a screen placed between the ear and a sounding body does not effect the sound reaching the ear.

   Illustrations of light travelling in straight lines is seen by watching a ray of light in a darkened room or the beam from a search light at night.

   Light is *invisible,* but when it falls on anything it makes that thing visible.

   Illustration—If a ray of light is admitted to a darkened room we see numerous little dust particles floating through the light and these particles are nowhere else visible in the room. If there are no dust particles the ray of light cannot be seen unless we look directly towards the source of light.

   A **Ray** is one line of light. A **Beam** is several parallel lines of light.

6. **Velocity.** Light travels in straight lines at the rate of 186,000 miles per second. The velocity is less in liquids and solids than in the air.

7. **Intensity of Light** is the quantity of light that falls on a given surface. Intensity of Light depends on:
   - (*a*) Source of Illuminating Power; as, we get more light from an electric light than from a candle.
   - (*b*) Distance. The further away we get from the source of light, the less intense the light becomes.
   - (*c*) The Visual Angle. The angle made by the light coming from the extremities of an object to the center of the eye. The farther away the eye is from the object the smaller is the visual angle under which it is seen, therefore the object oppears smaller and the light is less intense.

8. **Radiation** is the propagation of ether waves through space.

9. **Radiant Energy** is the energy carried by ether waves. The part of radiant energy that can excite vision is *light.*

SHADOW.

This is the darkened space where an opaque body has cut off the light.

The shape of the shadow depends on the position it is in, with regard to the illuminating body. (Example—Shadows at noon and in the afternoon.)

PARTS OF A SHADOW.

Umbra. The central and darkest part of the shadow.

Penumbra. The partial shadow surrounding the central portion or umbra.

Experiment—Place an object close to a white screen opposite a flame of light while the object remains in this position the shadow is all dark, no penumbra showing; but move the object nearer the light and the two parts of the shadow are seen, the center from which all light is excluded being the darkest part or *umbra*, while the space beyond receiving some portion of light from the flame, but not all, is *penumbra*. The size of the penumbra decreases as the object is moved toward the screen or as the source of light diminishes.

THE MOON.

The **Phases** of the moon are the different portions of the illuminated surfaces which are seen on the earth as the moon revolves around it. They are NEW MOON, FIRST QUARTER, FULL MOON and LAST QUARTER.

New Moon occurs when the moon appears on a straight line between the sun and earth. The moon being a circular solid has half its surface which is turned toward the sun illuminated; the other half turned toward the earth is in darkness having no light of its own, so is invisible to persons on the earth directly opposite the moon. But as the moon moves in its orbit a small portion becomes visible and this is known as the New Moon.

Full Moon. The moon and sun are on opposite sides of the earth. The sun shining on the half of the moon turned towards the earth, makes it appear to the people on the earth opposite it as a full circle of light known as full moon.

First and Last Quarter. The moon and sun are at right angles to the earth. The sun shining on the moon lights up the half turned towards it; but only one-half of the part of the moon turned towards the earth is visible, so we see but a quarter of the moon.

ECLIPSES.

An **Eclipse** is the obscuring of one of the heavenly bodies by another coming between it and the sun or between it and the spectator.

A Solar Eclipse is one caused by the moon coming between the sun and the earth. It always occurs at the phase of new moon when the sun and moon are in conjunction.

The moon being an opaque body casts a shadow on the earth and for a small space cuts off the light from the sun. Persons in the space experience a *solar eclipse*. It lasts but a very short time as the earth is rotating constantly.

A Lunar Eclipse is caused by the moon passing through the earth's shadows. It always occurs at the phase of the full moon when the sun and moon are in apposition, that is on opposite sides of the earth.

The earth being opaque casts a shadow on the moon and cuts off the light on the moon where the shadow falls, so persons on earth opposite the space where the shadow occurs experience a lunar eclipse.

REFLECTION.

1. A change in the direction of the rays of light without a change of medium is called *reflection*.

LAW—In reflection the angle of incidence equals the angle of reflection.

EXPERIMENT—Allow a ray of light to enter a darkened room and strike the surface of a mirror at an angle of 45 degrees. The light will be reflected on the ceiling forming an angle of 90 degrees with the ray. The angle between the ray and the normal or vertical plane of the mirror known as the angle of incidence, will be seen to equal the angle between the vertical plane of the mirror and the reflected ray known as the angle of reflection.

When rays of light fall upon a body these rays must be *reflected, diffused* or *absorbed* by the body.

Experiment—If the ray falls on a piece of unglazed white paper instead of the mirror there will be no reflected beam, but the room becomes brighter, the beam having been diffused or scattered by the many little rough particles of reflecting surface of which the paper is made up.

Experiment—If the beam falls on a piece of black material instead of the paper or mirror there will be no reflection or diffusion, the light having been absorbed by the dark material.

MIRRORS.

A **Mirror** is a body which reflects a large amount of light from its surface.

Three Classes of Mirrors—Plane, convex, concave.

(a) **Reflection in Plane Mirrors.**

An image is the picture of a body formed by the rays of light coming from it

(1) **Images Are of Two Kinds.**

1. REAL IMAGE is one that may be seen on a screen, or is an image that is actually formed.

2. VIRTUAL IMAGE is one that cannot be seen on a screen but appears behind a mirror. It is only an apparent image.

(2) **Simple Images in Plane Mirrors.**

1. The image of an object appears as far behind a plane mirror as the object is in front of the mirror.

2. Images in plane mirrors are inverted laterally. Hold a printed page facing a mirror and the printed page will be inverted from left to right. Stand before a mirror and raise the hand on the left side, the image will appear to have the opposite hand raised.

3. Images are the same size as the objects.

(3) **Multiple Images in Plane Mirrors.**

1. The number of images reflected with two mirrors depends upon the angle at which they are placed. The number of images seen will be the number of times the angle at which they are inclined is contained in 360 degrees, the circumference of a circle, hence if they are inclined at 60 degrees there will be six images seen.

2. When two mirrors are parallel, facing each other, with an object placed between them, the number of images reflected depends upon the distance the object is from the mirrors.

Illustration—Kaleidoscope is constructed on the principle of reflection of multiple images. It consists of a tube containing three mirrors placed at angles of 60 degrees. Pieces of colored glass free to move at one end of the tube are seen through an eye-piece at the other end of the tube. These pieces of glasses by repeated reflections are multiplied showing many images of the colored glass.

(b) **A Concave Mirror** is similar to the inside of a spoon. Images seen in it appear distorted sometimes inverted and usually larger. Such a mirror collects and converges the rays of light.

(c) **A Convex Mirror** is similar to the outside of a spoon. Images seen in it appear distorted, usually smaller and right side up. Such mirrors diverge or spread apart the rays of light.

LENSES.

A Lens is a piece of glass bounded by two curved surfaces or one curved surface and one plane surface. The curved surfaces are usually spherical.

1. **Converging Lenses.**

Those that are thickest in the middle and cause the rays of light to converge after passing through them.

Let water gently trickle over the lens held horizontally and it will run towards the center, the lowest point, and from there drip off in drops. Light acts the same as water.

The point at which the rays all meet is called the *focus,* and the distance from the center of the lens to the focus is the *focal length* of the lens.

Three Classes of Converging Lenses.

(*a*) DOUBLE-CONVEX. Both surfaces convex.
(*b*) PLANO-CONVEX. One plane and one convex surface.
(*c*) CONCAVO-CONVEX. One concave and one convex surface.

2. **Diverging Lenses.**

Those that are thinnest in the middle and thickest at the edges and cause the rays of light to diverge after passing through them.

Three Classes of Diverging Lenses.

(*a*) DOUBLE-CONCAVE. Both surfaces concave.
(*b*) PLANO-CONCAVE. One plane and one concave surface.
(*c*) CONVEXO-CONCAVE. One convex and one concave surface.

REFRACTION.

The bending of a ray of light as it passes from one medium to another is called *refraction.*

EXAMPLE—A spoon in a tumbler of water appears bent and broken at the point where it passes from the air to the water.

This is due to the change in velocity as the light passes from one medium to another.

PRISM AND SPECTRUM.

By passing a ray of light through a glass prism the light may be dispersed or separated into a great many colors blending into one another, seven of which stand out distinctly. These are called the *solar spectrum* or the colors of the *rainbow.* They are: Violet, indigo, blue, yellow, green, orange, red, (vibygor).

A Rainbow is caused by reflection and refraction of the rays of sunlight by drops of rain. The water acts as the prism and disperses the light into seven colors, which are reflected in the sky so we find the rainbow opposite the sun.

Color of a body is due to its property of reflecting or transmitting rays of only *a particular kind.*

A body that absorbs all colors except red, reflects that color, and is said to be *red* in color.

A body that absorbs all colors is said to be *black;* one that reflects all colors is said to be *white.*

If light were not composed of the different colors there would be no difference of color in objects.

The **Primary Colors** are *red, green, violet.* They are called primary colors because by mixing these in different ways all the other rainbow colors are formed. All other spectrum colors are *secondary colors.*

Complementary Colors are any two colors that mixed together produce a white light, as blue and orange, yellow and indigo, violet and green.

TWILIGHT AND DAWN.

Twilight is the faint light after sunset, and dawn is the faint light before sunrise; both of which are produced by the reflection from the atmosphere of the sun's rays when it is below the horizon.

The different tints in the sky are produced by the separation of the rays of which the white light of the sun is composed by their passing through the moist lower atmosphere, just as they can be separated by passing through a glass wedge or prism.

IMAGES SEEN THROUGH SMALL OPENINGS.

If light from a luminous body is admitted through a small hole to a darkened room and there received upon a white screen, it will form an inverted image of the object, because light travels in *straight* lines.

OPTICAL INSTRUMENTS.

1. **Simple Microscope.**

This consists of a double convex lens of short focal length. It is used for observing very small objects. The eye is placed close to the lens and the object to be studied at a distance less than the focal length of the lens. The distance at which the object is placed varies for different persons.

The image is a virtual one, and will appear upright and larger than the object.

2. **Galilean Telescope.**

This has a double concave eye lens and, at the opposite end, a double convex lens. This brings the image very near. It is used for objects at a great distance, as the concave lens spreads the rays and focuses the image back of the eye if the object is too near.

A pair of these telescopes placed side by side form an *opera glass.*

3. **Magic Lantern.**

A magic lantern is an instrument for throwing on a screen an enlarged picture of a transparent photograph called a *slide.*

A light is placed at the common focus of a concave mirror and a convex lens. A powerful beam of light is thus thrown on the transparent slide. A compound objective lens is placed at a certain distance beyond the slide. The tube containing the objective lens is adjustable, so that the image may be made to fall on the screen distinctly. The slide must be inverted in order that the image may appear right side up. Two magic lanterns placed so as to coincide form a *stereoptican.*

4. **Camera.**

A common camera consists of a lens placed in one end of a dark box. The sides of the box are usually flexible so that the distance between the lens and the screen can be changed in order to focus the object properly, as the distance between the object and the camera changes. The movable screen is made of ground glass, and is moved to the focusing point so the object can be examined by the eye. To secure a picture of the object a sensitive plate is put in place of the screen and is exposed to the rays of the light coming from an object. The rays of light from the object form a laterally inverted image.

THE EYE.

It has for its outer wall a tough membrane called the *sclerotic coat.* Inside of this coat is a delicate membranous lining called the *choroid coat* which is dark in color and so prevents the internal reflection of the rays of light that enter the eye. The third or inner lining is the *retina,* which is a translucent membrane at the back part of the eye, formed by the expansion of the optic nerve and is very sensitive to light.

In front of the eye is the *cornea,* a thin, hard, transparent substance, which is a continuation of the sclerotic coat. A little behind the cornea there is a double convex lens named the *crystalline lens,* which focuses the object on the retina by becoming thinner or thicker as the object is far or near. In front of the lens is a circular colored curtain, the *iris,* which determines the color of the eye. This has an opening in the center, the *pupil,* which regulates the amount of light entering the eye. The ball of the eye behind the lens is filled with transparent, jelly-like substance called the *vitreous humor.* A liquid called the *aqueous humor* fills the space between the cornea and the crystalline lens.

How We See. By means of the crystalline lens the rays of light coming to the eye from an object are brought to a focus on the retina, when just as in the screen of the camera a laterally inverted image is formed. The retina is an expansion of the optic nerve and the optic nerve being stimulated by the rays, which come from the image, convey the impression to the mind or brain.

COMPARISON OF THE EYE AND A CAMERA.

1. Both have a lens.
2. Both have a dark chamber.
3. Both have a sensitive plate. In the eye it is called the retina.
4. Both have something to regulate the amount of light that enters. In the eye it is the iris and the pupil.
5. In the camera, the focus of the lens is adjusted by moving the screen closer to the lens for distant objects; and farther from the lens for nearer objects. In the eye by means of a delicate mechanism which works without our consciousness, the focal distance of the lens is increased and diminished by the changing of the curvature of the lens, flattening or thickening it. Thus for a distant object the retina does not move forward like the screen, but the crystalline lens becomes thinner and so brings the focus on the retina.

NEAR-SIGHTED AND FAR-SIGHTED EYES.

A Near-Sighted eye is one that cannot see objects unless they are very near the eye. This defect is usually due to the shape of the eye. The eye-ball being too long or the lens or cornea are too convex the image is formed in front of the retina.

This defect is corrected by using concave lenses which spreads the rays of light and focuses the image back on the retina.

A **Far-Sighted** eye is one that can see objects at a far distance more clearly than if near the eye.

This defect is usually due to the shape of the eye. The eye-ball being too short or there being too little curvature to the lens, the image is formed in the back of the retina. This defect is corrected by using convex lenses which converge the rays of light focusing the image on the retina.

MAGNETISM.

A Magnet is a piece of iron which has the property of attracting other pieces of iron, and if it is freely suspended will point north and south.

Magnetism. This force that attracts the iron and steel is called magnetism.

The names magnet and magnetism were applied because the ore was first found near Magnesia, Asia Minor.

Classes.

1. **Electro-Magnets.** Those made of soft iron and which only retain their power for a short time.
2. **Permanent Magnets.**

(*a*) Artificial Magnets.—Those made of hard iron or steel usually in the shape of a bar or horseshoe. These retain their magnetic power for a considerable time.

Armature. A bar or piece of soft iron known as the armature is placed over the poles to prevent a loss of magnetism when not in use.

(*b*) *Natural Magnets.*—The iron ore called lodestone originally found in Magnesia but since found in considerable quantities in Siberia and Scandinavia.

Poles. The ends of a magnet where we find the greatest attraction. This is known as *polarity.*

The end in a freely moving magnet which points toward the north is called the North seeking or North Pole and is in dicated by + (plus), the other pole is called the South seeking or South Pole and is indicated by — (minus).

Magnetic Meridian. The direction which the needle takes when at rest.

Experiment (*a*)—Dip a magnet in a paper of iron filings and the filings will cling thickest at the end and scarcely at all towards the center.

Experiment (*b*)—Magnetise a knitting needle by rubbing it in one direction on a permanent magnet, then suspend it by a thread tied around the middle. Mark the end pointing toward the north. Swing the needle and allow it to come to rest and it points again in the same direction north and south.

Magnetic Force is the power exhibited by a magnet at its poles.

Magnetic Field is the space through which the influence of the magnet is felt.

Experiment—Place a bar magnet on a table and bring near it a sewing needle, as soon as the needle comes within the magnetic field it is drawn quickly toward the magnet.

Lines of Force are the lines of magnetism radiating from the magnet shown by the way the iron filings arrange themselves about the magnet.

Molecules of Magnetism.

If a magnet is broken in pieces each piece becomes a complete magnet, a new north pole appearing on the part which had the original south pole, and a new south pole appearing on the part which had the original north pole.

MAGNETISM has to do with the arrangement of the molecules, for if a magnet be hammered or jarred it loses some of its force, and if it is heated red hot it loses its magnetism entirely.

EXPERIMENT—Fill a small thin glass bottle with iron filings and stroke it from top to bottom several times with a magnet and it becomes itself a magnet; but if the filings are shaken up it loses its attractive power.

Laws of Magnetism.

1. *Like* poles *repel.*
2. *Unlike* poles *attract.*

EXPERIMENT—Bring the south pole of one magnet near the north pole of another magnet, and they are drawn towards each other. Then bring the two north poles together and we find there is no attraction, and if freely suspended one north pole moves away from the other. The same is true if two south poles are brought together.

Magnetic Induction.

The temporary magnetism produced by the near presence of a magnet with or without contact is called *induced magnetism.*

EXPERIMENT—Dip a nail in some iron filings and there is no attraction. Place the nail in contact with a magnet and dip it again into the filings and we find that it has now acquired magnetism which it loses upon being removed at a distance from the magnet.

Magnetic Needle.

A magnetic needle is a bar magnet freely suspended so as to take a north and south position.

Classes.

(*a*) MARINER'S COMPASS.
(*b*) DIPPING NEEDLE.

1. Mariner's Compass.

It is supposed to have been introduced from China into Europe in the last part of the Twelfth Century.

A thin piece of magnetized steel is balanced on a steel pivot so that it is free to move in a *horizontal* plane. The magnetic needle points toward the north and south magnetic poles of the earth. Under the needle is a card containing the scale with the points north, east, west, etc., indicated on it. All of the above is fastened in a case which is attached to the vessel. Should the vessel start in a northerly direction and we glance at the card we will see that it indicates that the needle is pointing north. Later the vessel sails directly east and we find the needle according to the card apparently points west; but as the needle always points north the vessel must have turned, and as the point north is now 90 degrees to the right of the needle we know that the vessel to which it is attached must have moved through that space, making the direction due east.

2. Dipping Needle.

This is a magnetic needle suspended to move freely in a *vertical* plane. The dip or inclination the needle makes with a horizontal line is read in degrees on the scale attached to the instrument. This dip varies in different places on the earth. At the magnetic poles the needle is vertical, as it moves away it inclines less and less until it reaches a point where there is no dip or inclination. A line connecting these places is called the *magnetic equator.*

Miners or geologists use dipping needles in searching for iron ore.

Experiment—Over a bar magnet suspend a needle perfectly balanced. Move it along the magnet from pole to pole. At the center of the magnet the needle is horizontal, but as it moves in either direction from the center it dips until at the poles it is vertical, opposite ends of the needle being drawn towards the different poles.

Magnetic Declination.

Magnetic needles never point to the true north, but a little east or west of it, and this variation from the true north is called the *declination.*

The magnetic north pole is about 70 degrees north latitude and 96 degrees west longitude, so places on the eastern coast of the United States point west of the true north in pointing toward the magnetic pole and places on the western coast point east of the true north.

Magnetic Inclination is the angle that the magnetic needle makes with a horizontal line on the earth.

Terrestrial Magnetism.

1. The earth is a magnet because it has magnetic attraction power.
2. Magnetic north and south poles.
3. Magnetic Equator.

FRICTIONAL OR STATIC ELECTRICITY.

The ancient Greeks over 2,000 years ago discovered that amber or ELECTRON if rubbed with silk would attract small light bodies as bits of paper, cork, pith, etc.

In latter years it was discovered that various other bodies by friction acquired the same property as electron and they were said to be electrified.

Static Electricity is produced by friction and stands or remains on the outside surface of body, and does not penetrate to the interior.

Experiment—Rub briskly a glass rod with silk, a piece of sealing wax with flannel, a rubber comb with flannel and bring each in contact with small pieces of paper and we find the paper is attracted to all of them.

Kinds of Electricity.

(*a*) Negative.
(*b*) Positive.

For convenience the kind of electricity produced by rubbing sealing wax with flannel has become known as *negative* electricity, while that produced by rubbing glass with silk has become known as *positive.*

Laws of Electricity.

1. An electrified body attracts an unelectrified body.

Experiment (*a*)—Bring the electrified glass rod near the bits of paper and they are attracted to the rod. Repeat the experiment using electrified sealing wax or rubber.

EXPERIMENT (*b*)—Rub a sheet of paper briskly with rubber and bring it in contact with the wall, it is attracted and remains fastened to the wall for a time.

2. Bodies charged with the same kind of electricity repel.

   EXPERIMENT—Electrify a glass rod and place it in a stirrup. Bring near it another electrified glass rod, and the first rod moves away from the second. Repeat, using two pieces of electrified sealing wax with the same result.

3. Bodies charged with unlike kinds of electricity attract.

   EXPERIMENT—Suspend in a stirrup an electrical glass rod and bring near it an electrified piece of sealing wax and the rod moves toward the wax, showing attraction.

4. Both kinds of electricity are always developed at the same time when two bodies are rubbed together.

   EXPERIMENT—Electrify a glass rod and suspend it. Electrify a second glass rod and bring the silk near the first rod and we find attraction, showing that both kinds of electricity were present. Then bring the second rod near the first and we find a repulsion showing that the silk and glass had each a different kind of electricity developed in them.

ELECTROSCOPE.

This is an instrument for determining if a body is electrified.

EXPERIMENT—To make an electroscope, fasten with sealing wax a piece of glass tubing to a small wooden block. At the other end of the glass tube fasten with sealing wax a bent wire and attach to this a pith ball by a silk thread. Silk being used because it is a non-conductor.

Present an electrified body to the pith ball and as electrified bodies attract unelectrified bodies the pith ball will be drawn to the electrified body. As soon as it comes in contact the pith ball acquires by induction some of the electricity and is then repelled, as like electrified bodies repel each other.

ELECTROPHORUS.

This is the simplest kind of an instrument for producing electricity.

EXPERIMENT—To make and charge an electrophorus. Into a tin plate, place and allow to cool a mixture of resin (three parts) and beeswax (one part) or else melted sealing wax. Rub with cats' fur or flannel the resin surface, being careful to hold the plate with a cloth so that the fingers do not come in contact with the metal. Place a metal cover smaller than the tin plate with an insulated handle over the mixture. Press the upper surface down with the finger and remove it, then touch the cover against the knuckle and a slight shock of electricity will be felt.

In rubbing the wax a negative charge is developed on the surface and the positive is repelled to the under side next to the tin plate. When the cover is placed on the wax surface it will only touch in a few places as the surface is uneven, and so by induction a negative charge will be found on the lower surface of the cover, the positive rising to the top and escaping when the disk is touched with the finger.

LEYDEN JAR.

This is known as a condenser because it is used to collect and hold small charges of electricity. When the jar is discharged we should feel a slight shock or see a spark.

The leyden jar consists of a glass covered inside and outside three-fourths up with tin foil. A tight fitting wooden cover is placed on the jar with a metal rod running through it with a knob at one end and a chain at the other, reaching to the bottom of the inside of the jar.

The jar may be charged by touching the cover of the electrophorus to the metal knob. It may be discharged by making a connection between the outside tin foil and the metal knob. This may be done by placing the little finger on the outside tin foil and the thumb on the knob. Dischargers are also used—this is a piece of curved metal with an insulated handle. The tin foil should be touched first in discharging the jar.

CONDUCTORS AND NON-CONDUCTORS.

A Conductor is a body which has the ability to conduct or permit electricity to readily pass through it; as, metals, diluted salts or acids, water, moist air, linen, cotton.

A Non-Conductor or Insulator is a body which retains the electricity, or does not permit the electricity to readily pass through it; as, dry air, paper, sealing wax, resin, glass, rubber, wood, silk. Sulphur is almost a perfect insulator in all weather. No very distinct line can be drawn between conductors and non-conductors.

When a conductor is separated from other bodies by a non-conductor so that the electricity cannot be carried to the earth and lost, it is said to be *insulated.*

If a body is warm, dry and perfectly clean it is more easily electrified.

LIGHTNING AND THUNDER.

Lightning is a huge spark or a form of frictional or static electricity, passing through the air between two clouds or between a cloud and the earth. The atmosphere is electrified even in clear weathr. The flash of lightning is the discharge between the two surfaces oppositely and highly electrified, coming closely together.

Thunder is the noise due to the great disturbances in the air produced by lightning. The air along the line of discharge being heated by friction produces sudden expansion and compression, thus forming a partial vacuum which filled by the surrounding air rushing in with great force produces the sound we call thunder. The discharge moves so rapidly that an irregular hole is left in the air it passed through, and, there being a pressure of 15 pounds on each square inch of surface, the walls come together with a great crash, but at a distance it has a rolling sound due to echo.

In hot weather we have what is known as *heat lightning,* that is flashes of lightning occur without thunder following them. This is supposed to be due to a discharge at a great distance, so great that we only see the light as reflected by the clouds.

Lightning may be illustrated by the discharge of a leyden jar, two conducting surfaces, tin foil, separated by a non-conductor, the glass jar; corresponds to the two conductors, earth and cloud separated by the non-conductor, air.

Lightning Rods are pointed metal conductors projecting above a house and extending downward deep enough to be surrounded constantly with moist earth or into water, both of which are good conductors. They not only conduct the electricity to the earth in case of a stroke of lightning, but frequently prevent violent discharges by allowing the negative electricity of the earth to pass off quietly into the air at the top and so neutralize the positive electricity of the clouds or air above. The lightning rod was invented by Benjamin Franklin in 1752.

Aurora Borealis or Northern Lights is a strange electrical display seen in the polar regions, probably due to the discharge between the differently electrified portions of air coming from the poles and meeting that from the tropics in the higher and thinner layers of atmosphere.

CURRENT OR VOLTAIC ELECTRICITY.

Voltaic Electricity is electricity produced by chemical action generated by means of a battery or cell.

It derived its name from its original inventor Volta, the Italian, who found that two dissimilar conductors and a liquid dissolving one of them would create a current of electricity. Such a combination is known as a *cell,* the two metals being the *elements,* and the ends of the plates to which the wires are fastened, the *poles* or *electrodes,* water and acid, the *exciting fluid* which produces the chemical action.

The name *battery* is applied to a single cell or to a number of such cells connected by a conductor.

Electric currents only flow when we have a closed circuit, that is when the two poles are connected by a conductor.

Voltaic Cell. This consists of a zinc and a copper plate placed in a vessel containing diluted sulphuric acid.

Types of Cells. There are many commonly used and these generally have a zinc rod to be acted upon; as Le Clanche, Daniell, Bi-Chromate and Dry.

Le Clanche Cell. This consists of a glass jar into which is placed a zinc rod; also, a porous cup sealed at the top containing a carbon plate around which is packed manganese dioxide and coke. The exciting fluid is a solution of sal amoniac and water. This cell is good for ringing door bells.

Bi-Chromate Cell. This is usually in a bottle form containing two carbon plates suspended from the cover with a zinc rod or plate arranged between them, so that it can be removed from the liquid when not in use. The exciting fluid is potassium bi-chromate. This cell is good for telegraphs and motors.

Daniell Cell. This consists of a porous cup containing a copper plate in copper sulphate dissolved in water. Outside of this cup is a zinc rod or plate in a zinc sulphate solution. This cell is good for telegraphic purposes.

Dry Cell. This is a modified form of the Le Clanche cell. Instead of a fluid, the metals are imbedded in moist paste, but the action is the same as that of the Le Clanche cell. This cell is good for electric bells and telegraphs.

Arrangement of Cells.

If a current of electricity is to be sent through a long, thin, small wire, the cells should be arranged in *a series,* that is the zinc plates should each time be connected with the other metal in the next cell; copper, carbon or whatever is used, leaving as terminals a copper on one side and a zinc on the other.

If a current of electricity is to be sent through a short, large wire the cells should be arranged *in parallel,* that is all the zinc plates should be connected with one terminal and all the other metal plates (copper) arranged in similar manner connected with one terminal.

TERMS.

Potential is the electrical pressure or electro motive force by which the current is driven through the wire.

Volt is the unit of electromotive force. The name is derived from the scientist Volta.

Ohm is the unit of resistance, all substances do not allow the electric current to pass through with the same ease. This difference in resistance is measured by ohms.

Ampere is the unit of strength of a current of electricity.

Galvanometer is an instrument for measuring the strength of a current.

Conductors and Non-Conductors or Insulators.

EXPERIMENT—Pass different materials between the poles of a battery or of any electrical apparatus. If the current passes through the material it is a conductor, but if not, we have a non-conductor.

ILLUSTRATIONS:

CONDUCTORS—Metals, as iron, brass, steel, tin, silver, gold, copper, etc.

INSULATORS—Wood, glass, rubber, silk, woolen goods, paste board, wax, etc.

ELECTRO-MAGNET.

This is a bar of soft iron generally in the shape of a horseshoe, consisting of two spools mounted on two perpendicular pieces of iron set in a piece of iron. Around the spools a coil of insulated wire is wound. Across one end of the magnet is a bar of iron called an armature or insulator. A current of electricity is passed through the wire causing the soft iron to acquire the properties of a magnet as long as the current is flowing and so attracts the armature to itself.

USE—Electro-magnets are used in electric bells and telegraph instruments. Some electro-magnets are very powerful and are used to magnetize bars of steel.

EXPERIMENT—Wind insulated copper wire around a wire nail or soft piece of iron. Dip this into the iron filings and we find there is no attraction. Connect the two bare ends of the wire with a battery, permitting a current of electricity to flow through the wire. Then dip the nail again into the iron filings. This time the filings were attracted to the nail the same as though it were a magnet. Disconnect the wires and the nail is no longer a magnet, and the filings drop off.

ELECTRIC BELL.

This consists of an electro-magnet across which an armature is placed, at one end of which is a metal wire which ends in a small metal ball. When the circuit is closed by pushing the button, the current flows through the wires and draws the armature against the electro-magnet and so causes the bell to ring. As soon as the armature touches the electro-magnet the circuit is broken between the armature and a stop connected with the battery. When the circuit is broken the electro-magent loses its power and the armature springs back to its original position so closing the circuit, and the bell again rings if the finger has remained on the push button and the same thing is repeated.

ELECTRIC BUZZER.

This is the same as an electric bell with the bell part removed and is used where the loud ringing of a bell would be objectionable.

TELEGRAPH.

The first telegraphic line to be used in business was made by Morse in 1844 and ran between Baltimore and Washington.

The *principle* upon which the telegraph works is the making and unmaking of an electro-magent.

It is *necessary* for *telegraphing* to have a *battery* or *dynamo* to generate the current of electricity; a *wire* made of strong copper or iron to connect the different places; a *key* or *transmitter,* and a *sounder* or *receiver.*

Two lines were originally used in telegraphing, one wire being for the current to pass to the receiving station and the other wire for the return current. This is now only done in case of a very short line.

As a rule, now only one wire is used, the earth taking the place of the returning wire. The two ends of the wire being connected with large metal plates which are buried deep in the earth.

The **Sounder** is the part of the telegraph that receives the current from a distant place. By means of the electro-magnet and the armature fastened to a lever a short distance above the magnet it produces sounds or clicks exactly similar to the ones produced at the distant place by operating the key. These sounds are interpreted into letters and messages by their duration, number and arrangement. Two clicks coming close together is called a dot. Two clicks coming some time apart is called a dash. The different groups of dots and dashes indicate letters of the alphabet.

TELEGRAPHIC ALPHABET.

a	b	c	d	e	f	g	h	i
- —	— - - -	- - -	— - -	-	- — -	— — -	- - - -	- -
j	k	l	m	n	o	p	q	
— - — -	— - —	—	— —	— -	- -	- - - - -	- - — -	
r	s	t	u	v	w	x	y	z
- - -	- - -	—	- - —	- - - —	- — —	- — - -	- - - -	- - - -

The **Key** is that part of the telegraph by which the circuit can easily and quickly be opened or closed. It consists of a lever held in place by a spring and is operated by pressing the knob against a stop. When this is done a click is produced in the sounder of that instrument and a similar sound in the distant instrument to which the message is sent. When the finger is removed from the knob it springs back to the original position.

A **Switch** is connected with the key. When not in use the circuit is closed by the switch so allowing the current to pass through the key and along the main wire, so that messages may be received. When a message is to be sent the switch is opened.

Relay. If a message is sent over a long wire, the current when it reaches the receiving station is too weak to pull down the armature of the sounder, so to remedy this a *relay* is used, that is an electro-magnet around which is wound many coils of fine wire and connected with the main line.

In sending a message to a distant place it may be read at any intervening station; but each place has its own call, so intervening places not receiving their call will take no notice of the click.

TELEPHONE.

This is an instrument for transmitting speech to a distant place by means of electricity. It was invented in 1876 by Gray of Chicago, and Bell of Washington.

PRINCIPLE—A current of electricity may be induced in a coil of wire by holding it near a magnet and varying the number and direction of the lines of force coming from the magnet.

The Receiver consists of a permanent bar magnet around one end of which is wound a coil of insulated copper wire, the terminals of which pass through the receiver and are connected with the binding posts at the end. A thin flexible sheet iron disk is held in place across the ends of the insulated wire, but does not touch the magnet.

Mouth-Piece or Transmitter consists of a magnet, a disk touching the magnet, and a thin flexible plate near but not touching the disk.

ACTION—Speaking into a transmitter will cause the sound waves to beat upon the thin metal plate and cause it to vibrae. These vibrations change the lines of force coming from the magnet through the disk and produce a current of electricity in the wire which is carried to the distant receiver and passing through its coil will set up similar vibrations in its flexible iron sheet and thus reproduce the original sounds uttered into the transmitter.

DYNAMO.

This is a machine for producing electrical currents by mechanical means, usually by steam or water power.

PRINCIPLE—The producing of a current of electricity in a conductor or coil of wire by causing it to move through a magnetic field, thereby changing the lines of force.

The dynamo consists of

1. The **Armature** which is a soft iron core around which is wound coils of insulated copper wire and so arranged as to rotate rapidly and continuously in a magnetic field. A shaft running through the armature connected by belts with some steam or water power is usually the means by which it is rotated.
2. The large powerful **Magnet** for creating a magnetic field.
3. The **Commutator** gives a uniform direction to the currents.

USE—Dynamos produce electricity for the motors which run the electric cars, lights, etc.

ELECTRIC MOTOR.

This is a machine for changing electricity into mechanical power. In general its form, construction and chief parts are the same as the dynamo, but it acts oppositely to the dynamo. In the dynamo a current of electricity is generated by mechanically revolving the armature in a magnetic field, while in the motor the armature revolving by the electricity is attached to a shaft, belt or wire which turns the machinery to do the work, as in electric fans, sewing machines, motor boats, automobiles, printing presses and other light machinery.

QUESTIONS ON SOUND.

A flash of lightning is seen and 3 seconds later the thunder is heard. How far away was the lightning, the temperature being 24 degrees C.?

Why can we hear the noise of an approaching train sooner by placing the ear upon the rail than waiting for the sound to come through the air?

What is meant by a vibration?

What is the velocity of sound at 32 degrees Fahrenheit?

How does the velocity of sound in air compare with it in a liquid or a solid?

What is the difference in sound if two strings of equal length and thickness, but one having a tighter tension than the other, are sounded?

What is the difference in sound if two strings of equal length and tension, but one being thicker than the other, are sounded?

What is the difference in sound if two strings of equal thickness and tension, but of unequal lengths, are sounded?

How is it we can hear sounds plainer on a foggy night on the water than on a clear night?

What is intensity of sound?

Upon what does intensity depend?

What is pitch?

Upon what does pitch depend?

What is an echo?

What is the difference between a noise and a musical sound?

How do the vibrations of the octave compare with the vibrations of the note itself?

How many vibrations has middle C?

What is the musical scale?

What is meant by a third, a fifth of the scale?

What is timbre?

QUESTIONS ON HEAT.

What is meant by heat? Cold?

What is temperature?

What is a thermometer? A barometer?

Why is the space between rails of a railroad greater in winter than in summer?

Why does glass crack on being suddenly heated?

Why does iron feel colder than wood even though the temperature is the same?

Why does snow warm the earth?

Why is water dried up in rivers in hot weather?

What is meant by boiling?

Can latent heat be changed to sensible heat?

Why is a glass of ice water soon covered with moisture if brought into a warm place?

Why is salt mixed with ice in freezing ice cream?

What is the difference between boiling and evaporation?

Why is salt put on a slippery sidewalk?

Why is flannel warm in winter and cool in summer?

Why do we blow on our hands in winter to keep warm and fan ourselves in warm weather to keep cool?

If there is a change of 70 degrees Centigrade in temperature, what is the equivalent change in Fahrenheit degrees?
Explain the lighting of a match.
What is the origin of winds?
Give the reason for the trade winds in the northern hemisphere blowing northeast.
What causes a "hot box" on a train?
Why is the handle of an iron sometimes made of wood?
Why do water pipes burst in freezing?
Why do clothes dry better on a windy day than on a still day?
Why is heat so oppressive on a damp summer's day?
Why are icebergs frequently surrounded by fog?
Why does watering a street in summer cool the air?
Why do fishes in a globe die if the water is not frequently changed?
Why is water put into a cellar to prevent vegetables from freezing?
If bodies expand when heated, why does mud crack on being heated by the sun?
Why will hot tea dissolve more sugar than iced tea?
Why are iron tires heated before being put on the wheels of a wagon?
Why is it more apt to be cloudy in the afternoon than the morning of a summer's day?
When sitting in front of an open grate fire do we receive heat by conduction, convection or radiation?
Will tea cool more quickly in a polished or a tarnished vessel?
Which is coolest on a warm day, a white coat or a black one?

QUESTIONS ON LIGHT.

What is light?
Distinguish between opaque, transparent and translucent bodies.
What are luminous bodies?
How fast does light travel?
What is a shadow?
Explain what is meant by umbra? Penumbra?
What effect has distance upon intensity?
From what source does the moon receive its light?
What is an eclipse? Name two.
Show the relative positions of earth, moon and sun at a total eclipse of the sun. Of the moon.
Does the earth receive more light from the sun in January or in June? Why?
Give the positions of sun, moon and earth at full moon, new moon, last quarter.
Explain why images seen through small openings are inverted.
What is meant by "the angle of incidence equals the angle of reflection?"
What is the difference between a real and a virtual image?
How does an object compare with its image seen in a plane mirror?
Explain what is seen when an object is placed between two parallel mirrors.
If two mirrors are placed at an angle of 60 degrees, how many images of the object placed between them can you see? Explain.
Is the image seen in a concave mirror larger or smaller than the object? In a convex mirror?
Name and classify the different lenses.
Describe the image found by a concave lens. A convex lens.

Why is it not dark as soon as the sun sets?
Why is a room with white walls lighter than one with black walls?
What occurs when light passes from one medium to another?
On what does color depend?
Why is grass green? Soot, black? Snow, white?
What are the primary colors? Why so called?
What are complementary colors? Illustrate.
What is the spectrum?
Name in order the colors of the spectrum.
What produces a rainbow? When and where is it seen?
What is meant by near-sightedness? How is it commonly caused? How remedied?
What is meant by far-sightedness? How is it commonly caused? How remedied?
Can a diverging lens be used as a "burning glass"? Why?
Describe a magic lantern.
Describe a simple camera.
Describe a microscope.

QUESTIONS ON MAGNETISM.

What is meant by magnetism?
Give the law of attraction and repulsion and an experiment to prove the same.
What is lodestone?
Show that magnetism acts through glass, cardboard.
What is the effect of heating a magnet red hot?
What is induced magnetism? Give an experiment to illustrate this.
What is meant by lines of force?
What is meant by magnetic field? The polarity of a magnet?
What are the different kinds of artificial magnets?
What material should be used for a permanent magnet? Why?
What happens when a magnet is broken in pieces?
Where is the north magnetic pole?
What direction does the magnetic needle point?
What is the difference between a dipping needle and a compass?
What is the meaning of the declination of the needle? The inclination?
What position does a needle take if suspended over the north pole of a magnet? The equator? The south pole?
Give three proofs of the existence of terrestrial magnetism.
What is a natural magnet?
Why is an armature placed over the poles of a magnet when not in use?

QUESTIONS ON FRICTIONAL ELECTRICITY.

What is meant by static electricity?
How can you determine the kind of electricity with which a body is charged?
How can you prove that two bodies rubbed together produce both positive and negative electricity?
Why is a pith ball first attracted to an electrified rod and then repelled from it?
Explain why a metal rod held in the hand and rubbed with silk shows no electrification but if held with a piece of rubber is soon electrified by rubbing with silk.
What is another name for a non-conductor?

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What is a conductor? A non-conductor?
What is the law of attraction and repulsion?
What is an electroscope? Describe one.
Why is a leyden jar called a condenser?
Describe a leyden jar.
How can a leyden jar be charged? Discharged?
What is an electrophorus? Describe one.
How is it charged? Discharged?
Why is a lightning rod pointed?
Why are lightning rods used?
Why cannot a conductor be electrified as readily as a non-conductor when held i the hand?
Is static electricity found in the charged body or only on the outer surface?
What is a simple machine for generating static electricity?
Explain how lightning and thunder is produced.

QUESTIONS ON CURRENT ELECTRICITY.

What is meant by a cell? A battery?
Name some cells commonly used?
What is an electrode? A pole?
What is meant by the elements of a cell? The exciting fluid?
What are the necessary parts of a Voltaic cell?
Of a Le Clanche cell?
What is an ampere? Ohm? Volt?
Describe how an electro-magnet is made.
What principle is involved in the electric bell and telegraph?
Describe the action of an electric bell.
What is necessary for telegraphing? Describe each of the principal parts.
Of what use are relays in telegraphing?
Explain how one person can hear another talking in the telephone. Describe the principal parts.
Give the main parts of a dynamo and their use.
How does the motor differ from the dynamo?
What are insulators? Name some.
How can you tell when a certain material is a conductor or not?
Under what conditions may an electric current be produced by a magnet?
If only one wire is necessary in telegraphing, how is a return current possible?
What is a dynamo? What is a motor?